THE DEVELOPMENT OF CONCEPTS OF MAGNITUDE

BY
MARTHA E. THRUM

A DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS HOPKINS UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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The Development of Concepts of Magnitude

MARTHA E. THRUM

THE development of the ability of children to perceive relative sizes of objects and make correct responses to the relation is a subject about which we know little. It is rather apparent that children have concepts which differ from those of adults in regard to comparative sizes of objects in their environment. It is often noted that a child misjudges size in relation to himself as is demonstrated by his look of surprise when he cannot sit in a chair made for a doll.

Attempts have been made to gain more complete and accurate information as to just how a child interprets things about him. This problem is particularly difficult with the very young child because of his inability to comprehend language and the greater limitation in conveying his thought through language which is intelligible to adults. This difficulty with language makes it necessary to attack the problem in a very simple and often indirect manner. Perhaps because of the comparative recency of planned research in child psychology, and perhaps because of the difficulties encountered in attempts to secure information regarding the extent of a child's ability to interpret relationships from an adult point of view, little work has been done on the subject.

Oppenheim (6) says that a child learns very gradually to associate visual impressions with proper relations of objects in space, and that his undeveloped power of accurate observation added to this, is bound to make his reports unreliable. Johnson (5) states that the child's perception of differences in the size and form of objects doubtless excels his ability to indicate his discrimination.

The purpose of this study was to obtain information on the development of abstract concept of magnitude for children from two to five years of age. The relative differences in size of geometric forms was chosen as a means of securing this information. For such young children it was necessary to have the procedure and language used as clear as possible. The sets of geometric forms were so planned that for each set of a given form the relative differences in size were varied. The sets included the familiar forms of circles, squares, and triangles, and were made of black cardboard. For a small group a further set was used which included colored forms. The colors used were red, green, yellow, and blue.

The investigations so far undertaken which bear on the problem of a child's concepts of size, fall into the fields of

form perception, the recognition of relationships, and the learning of relative sizes. There has been considerable work done on form and color combined in the same experiment in an attempt to determine which of the two elements tends to influence a child's selection: if there is a preference shown at what age this appears, how long a child tends to prefer color to form or vice-versa, and what factors seem to bring about a change of preference. These studies are primarily a study of preference and few investigations report data on the perception of the relative size of an object in comparison with others. A brief review of these experiments will suffice to illustrate the great need for further work.

Baldwin and Stecher (1) used the Montessori cylinders to test discrimination of difference in the diameters and heights of cylindrical inserts and their corresponding holes. Three sets of 10 cylinders were used, the first varying in diameter, the second in both diameter and height, and the third in height only. The inserts were placed and taken out again in front of the child before he was asked to perform the test. It was reported that several children took out correctly placed cylinders in the hope of forcing into the hole another cylinder for which a place could not be found, and that much trial and error experimentation went on.

The Montessori tower was used for perception of differences in size. It is comprised of ten blocks to be placed one on another in order of size. The tower was first built by the experimenter, then knocked down, and the child was asked to build it in the same way. The smaller blocks seemed easier than the larger ones. Perfect performance was impossible for the two-year-olds. The time necessary to complete the performance decreased with an increase in age. The authors say that the Montessori tower is an attractive and familiar occupation for young children and gives an immediate index of the development of a child's knowledge of size relationships.

An experiment by Rice (8) on the orientation of plane figures, though it uses figures of uniform size throughout the experiment, involves a keenness of perception similar to that involved in the discrimination of slight size differences. The problem was to test, if possible, the age when a child either will, negatively, refuse to recognize *sameness* in two figures which are identical, but not in the same position on the page, or will, positively, indicate by some word or action that they would be the same if one or the other were turned part way around.

The portion of the study important for consideration was a test of discriminative perception in the selection of a design regardless of position such as the perception of diamonds vertically and horizontally placed in the first test period, and of two spoons, vertically and horizontally placed in the second test period. The tests were given to 226 children between the ages of two years seven months and nine years three months. In the tests the scores depended on the number of correct perceptions including the accuracy of orientation.

The conclusions were that the orientation on the page of plane figures

appears to rise rather suddenly as a factor in their perception between the ages of five and six, or between the standard kindergarten age and the standard first grade age. The break is apparently rather sudden for the individual child with little or no transition; and for the group it may be located much more exactly than one might expect. The degree of similarity with the figures used in the perception tests seems to bear little or no relation to the reaction toward the orientation of the figures on the part of the child.

Piaget (7) holds that young children are unable to interpret relationships unless they are definitely concerned with themselves. On the other hand, Isaacs (4) and Hazlitt (2) found that children at a very young age were able to perceive and respond to relations that involved fine discriminations and a certain knowledge of relationships, but were unable, in many cases, to state these relationships because of their limited use of language. Other investigators interested in a child's ability to make judgments found that, in general, young children were able to see relative differences before they were able to state them.

A study of the *Learning of Abstract Concepts of Size* was undertaken by Hicks and Stewart (3). This is, as far as could be ascertained, the only experiment which deals with the abstract concepts of size irrespective of color or form and is of particular interest.

The problem was to test two to five year old children on their ability to learn to select the middle size of three boxes. Six boxes were used. They were cubes open on one side and varied in size from fourteen centimeters to four centimeters. All were covered with red paper. A small toy was always placed under the middle-size box in order to help motivate its selection and to identify the correct response to the child.

The 6 boxes made up 4 series with 3 boxes in each. Each series was presented in such order that after a child had learned to select the middle-size box in one group, he was shown a new combination from which the *largest* box of the previous series had been dropped and a new *smallest* box added. By varying the position of the boxes during each series the factor of position as a possible basis of learning was eliminated. During a single practice period the 5 positions of a series were repeated 5 times. Thus 15 trials or choices were made by a child in the course of each practice period. Each series was presented until the child made a perfect record on the 15 trials constituting a practice period. The next series was presented at the next practice period. A child was dropped at the end of the sixth practice period if he did not get more than a third of the responses correct. The interval between practice periods was never less than one or more than three days.

There were 40 children used in this experiment: 10 in each group for ages two, three, four and five years. The examiner placed a screen in front of the boxes when arranging them; then said, "now we are going to play a new game. Here is a middle-size box, a big box (pointing), and a tiny box (pointing). There is a toy under the middle-

size box, but there is nothing under the big box or tiny box (lifting each box up to demonstrate). Remember, the toy is always under the middle-size box." Before beginning the test on the succeeding days, the examiner said, "do you remember how we played our game? The toy was always under the middle-size box. All right, find the toy for me."

The authors summarize their results as follows: The test was beyond the ability of 9 of the 10 two-year-olds; 52 per cent of the choices of the 9 children who failed the test were made on the basis of the position of the box; the 31 children who completed the test gave almost no evidence of selection on the basis of position; the number of errors and the number of practice periods decreased with age; success in learning the test correlated highly with the mental age for 10 of the three-year-old children; direction of attention to the boxes and an interest in making the correct choices were factors in success; the children who completed the test confused the middle-size box with the large one twice as often as with the smallest one; 68 per cent of the errors made by the 31 children who completed the test were on Series 1. Once having learned the concept of *middle-sizeness* in the first series of boxes, they were able to apply this concept to the succeeding series.

The writer's experience with children under experimental conditions, leads her to think that the low percentage of success among the younger groups might have been due to the long practice periods. The authors state that "direction of attention to the boxes and an interest in making correct choices were factors in success." Since a child was obliged to complete a practice period at one sitting, and since each practice period required 15 trials or choices, is it any wonder that a two-year-old child lost interest? Another factor which the writer questions is that a child was dropped at the end of the sixth practice period if he did not get more than a third of the responses correct. This is requiring the same standard for the two-year-olds that was required of the five-year-olds. To say that a two-year-old cannot learn to select the middle-size of 3 boxes because he takes a greater number of trials to do so, is hardly correct. It would be interesting had the experimenters found out how many trials were required of each age group.

PROBLEM

This investigation, a report of which follows, is concerned with the development of the concept of magnitude. The major problem was a study of a child's development of the concepts of big, little, and middle size, irrespective of the particular sizes presented. The experiment covered a period of several months. In this experiment there were three series of tests given: A preliminary series, or Series X; a series forming the main study, or Series Y; and a supplementary series, or Series Z in which colored cards were employed. The children who reacted in this study were enrolled in the Child Institute of the Johns Hopkins University. They ranged in age from two to four and a half years at the begin-

ning of the study. The records of 34 children were used. There were 20 boys and 14 girls.

Method and Results

Series X. The materials used in the preliminary series of this experiment were as follows: 3 bright red toy automobiles measuring $4\frac{1}{4}$ inches, 3 inches, and an $1\frac{1}{4}$ inches respectively in length; 3 white paper circles the diameters of which measure 4 inches, $2\frac{1}{4}$ inches, and $\frac{3}{4}$ inch respectively; 3 white squares, the sides of which measure 4 inches, $1\frac{1}{2}$ inches, and $\frac{1}{2}$ inch respectively. The automobiles were used because they were familiar to and liked by all the children. They were exactly alike except in size. The objects in Series X were presented in the following order: cars, circles, squares, and triangles. The children were allowed to play with the cars for a few minutes before they were placed in position for the experiment. If a child wanted to continue playing, he was told that after playing the "game" with the experimenter he could play with the cars alone for a few minutes.

In the testing situation the examiner placed the cars on a table in front of the child who sat opposite, then gave the directions: "Look at these (pointing to objects) very carefully and give me the one I ask you for. Give me the biggest one." The first sentence of the above directions was repeated for each testing situation. The second sentence was varied according to the relative size of the object which the particular test situation called for. The positions in which the materials were presented, and the size which the examiner asked for, are indicated in the chart given below;

Position	*Sizes requested*
1. Big, little, middle size	Big
2. Big, little, middle size	Little
3. Big, little, middle size	Middle size
4. Middle size, little, big	Middle size
5. Middle size, big, little	Middle size

It will be noticed that the object intermediate in size was never placed in the middle position in this series. The order of presentation and size requested, as given in the chart, were followed for all materials used in Series X. The subject was given no indication of the correctness of his choice. Only one choice was required of a subject at each sitting, *i.e.* five sittings were necessary to complete Series X.

Results. The results have been tabulated in various ways in order to find out what factors seemed to influence a child's choice of a particular size. The data are analyzed for the number of errors made in response to requests for particular sizes of objects in relation to the other objects presented and also for the order of presentation with reference to size. The possible influence of the form of the object is also considered.

The data for errors made in response to requests for a particular size, either big, little, or middle size, are given in table 1. By far the greatest number of errors were made for the middle size, fewer for the little one, and least for the big one. We find that 88 per cent of the choices were correct when the big object was requested, 68 per cent when the little object was requested, and 48 per cent when the middle size was requested. The per-

centage of errors in 20 choices ranged from zero to eighty per cent, with a mean of 41.6 per cent of errors for the four years eight months. The greatest number of errors made for the three sizes was 16 out of 20 choices, made by 2 children, 1 three years and eleven months old, and the other two years and five months old.

TABLE 1

Series X

Errors made in relation to size requested

REACTOR	AGE	NUMBER OF ERRORS				ERRORS IN 20 CHOICES
		Size requested				
		Big	Little	Middle	Total	
						per cent
1	2–1	4	3	7	14	70
2	2–	0	3	0	3	15
3	3–4	0	2	7	9	45
4	3–3	0	2	0	2	10
5	3–	0	0	12	12	60
6	3–6	0	0	10	10	50
7	2–11	0	2	11	13	65
8	3–1	0	1	12	13	65
9	3–11	4	4	8	16	80
10	3–11	0	0	0	0	00
11	2–5	0	0	12	12	60
12	2–5	0	4	12	16	80
13	3–2	0	3	12	15	75
14	2–4	2	1	9	12	60
15	3–7	0	0	0	0	00
16	4–6	0	0	8	8	40
17	4–	0	0	1	1	05
18	4–6	0	0	0	0	00
19	3–5	0	2	11	13	65
20	2–7	2	4	9	15	75
21	2–4	0	0	2	2	10
22	3–8	0	1	1	2	10
23	4–8	0	0	0	0	00
24	4–5	0	0	0	0	00
25	4–7	0	0	12	12	60
Total errors.....		12	32	156	200	
Number of choices...		100	100	300		
Per cent wrong.....		12	32	52		
Per cent correct.....		88	68	48		

group. Five children out of 25 chose correctly for all selections of the three sizes. These children ranged in age from three years eleven months to

TABLE 2

Series X

Percentage correct for order of presentation

REACTOR	PERCENTAGE CORRECT		
	Order presented		
	BLM	MLB	MBL
1	41	25	00
2	75	100	100
3	50	100	25
4	83	100	100
5	67	00	00
6	67	00	50
7	50	00	25
8	58	00	00
9	100	100	100
10	33	00	00
11	67	00	00
12	33	00	00
13	41	00	00
14	58	00	25
15	100	100	100
16	67	00	100
17	92	100	100
18	100	100	100
19	58	00	00
20	17	00	75
21	83	100	100
22	83	100	100
23	100	100	100
24	100	100	100
25	67	00	00
Mean.....	68	45	52

The mean per cent of correct choices for the order of presentation, BLM (big, little, and middle size) in which all 3 sizes were requested, was 68. For the order MLB, in which only the middle size was requested, there was a mean per cent of correct choices

of 45. The data for individual children are given in table 2. With the exception of one child, we find that the children were either 100 per cent correct in their choice of the middle size for all forms presented, or were 100 per cent incorrect. Eleven out of the 25 children were 100 per cent correct. The mean per cent of correct choices of the middle size in the order MBL was 52. There were 11 children who were 100 per cent correct in their selections in this order of presentation.

Another factor involved in the problem was the difference in form of the objects used. In table 3, the number of errors made for each of the forms presented are given. As has been stated above, the cars were used because of their immediate appeal. On the whole, fewer errors were made with the cars than with the geometric forms, the circles, squares, and triangles; but the difference was slight. Sixty-three per cent of the choices involving the cars were correct, 58 per cent correct for the circles, 59 per cent correct for the squares, and 60 per cent correct for the triangles.

Summary. The results indicate that more children were familiar with the idea of *big* in relation to the other two sizes presented than they were with little or middle size. Only 4 out of the 25 children made errors in their selection of the big forms, while 13 made errors when selecting the little one, and all but 7 made errors in their choice of the middle size form. The ages of the 4 children who made errors for the big form were two years one month, two years four months, two years seven months, and three years eleven months. These children made errors in their selections of the little and middle size forms also. Among those who made no errors in their selection of the big forms there were 4 who were not three years lod. They ranged from two years to two years

TABLE 3

Series X

Errors made in relation to form presented without reference to size requested

REACTOR	ERRORS MADE				
	CARS	Forms presented			TOTAL
		Circles	Squares	Triangles	
1	2	4	4	4	14
2	0	1	1	1	3
3	1	3	3	2	9
4	0	1	0	1	2
5	3	3	3	3	12
6	2	2	3	3	10
7	3	3	4	3	13
8	3	3	4	3	13
9	4	4	4	4	16
10	0	0	0	0	00
11	3	3	3	3	12
12	4	4	4	4	16
13	3	4	4	4	15
14	3	3	3	3	12
15	0	0	0	0	00
16	2	2	2	2	8
17	1	0	0	0	1
18	0	0	0	0	00
19	3	4	3	3	13
20	3	5	3	4	15
21	1	1	0	0	2
22	2	0	0	0	2
23	0	0	0	0	00
24	0	0	0	0	00
25	3	3	3	3	12
Total errors.....	46	53	51	50	200
Number of choices..	125	125	125	125	
Per cent wrong.....	37	42	41	40	
Per cent correct.....	63	58	59	60	

and eleven months. It would appear therefore that age had very little, if any, influence over the accuracy of selections.

It is difficult to determine what effect the order of presentation of the three sizes had upon the choices. In the positions MLB and MBL, in which only the middle size was requested, more errors were made in the first of these positions than in the second, but whether this was due to the position or to a learning factor, it is impossible to say.

Another factor which was analyzed in order to determine its effect upon the accuracy of selections was the difference in forms presented. Although the cars, which were presented first, were chosen correctly more often than the three geometric forms, the difference was not great, and the difference in relative accuracy among the geometric forms was negligible. It appears therefore that the various forms used had no appreciable influence on the correctness of the choice.

The accuracy of selections in this series seems to have been determined by the previous experiences of the child, rather than by any factors involved in the experiment itself.

Method and Result

Series Y. Following the preliminary series which was intended primarily to secure coöperation and understanding of instructions, Series Y was given. This series was presented to a group of 15 children twice, and to a group of 19 children once only. A retest was given to one group after an interval of 6 months to obtain an indication of the effect of ordinary experiences upon the development of concepts after the stimulation of the test experience. The materials were sets of black cardboard circles, squares, and triangles differing in size by 1 inch, $\frac{1}{2}$ inch, and $\frac{1}{4}$ inch in diameter or length of side. The largest circle was 3 inches in diameter and the smallest 1 inch; the largest square and triangle measured 3 inches on a side, and the smallest measured 1 inch. For each geometric form the order of placement relative to size was the same: that is,

Circles	Squares	Triangles
BLM	MBL	LMB

B represented big, L represented little, and M represented middle size. There were five steps which involved varying differences in the sizes of the forms used. The first step included forms that differed from each other by 1 inch in diameter or length of side, the second by $\frac{1}{2}$ inch, and the third by $\frac{1}{4}$ inch. In the fourth step there was a difference of 1 inch between the biggest and middle size card; in the fifth there was $\frac{1}{2}$ inch between the biggest and the middle size card, and $\frac{1}{4}$ inch between the middle size and the little card. A sixth step was introduced in which all the three forms used were 1 inch in diameter or in length of side. The last step was used as a check on a child's understanding of the problem. The remarks made by the children were recorded by the experimenter. The directions were the same as for the other five steps, *i.e.* the child was requested to give the examiner the biggest, littlest, or middle size one. As in Series X, the geometric forms were placed on a table

in front of a child who sat opposite the examiner.

The positions in which the forms were presented and the sizes requested are indicated in the following chart:

Group A

Circles, Position BLM. Big requested in the six steps.
Squares, Position MBL. Big requested in the six steps.
Triangles, Position LMB. Big requested in the six steps.

Group B

Circles, Position BLM. Little requested in the six steps.
Squares, Position MBL. Little requested in the six steps.
Triangles, Position LMB. Little requested in the six steps.

Group C

Same forms and positions as in Groups A and B. Middle size requested.

In this series the middle size was put in the intermediate position once. A child was requested to make only three choices a day. He was, for example, asked to select the big size form in the first step of the first group above, for the circles, squares, and triangles. The next day, he completed the second step in which the differences in size of the forms varied from the preceding step. This procedure was continued until he had finished the six steps for the three forms. A similar procedure was followed for the second group B, in which the little size was requested, and for the third group C, in which the middle size was requested. The directions given were the same as those used in the preliminary series; that is, the child was requested to give the examiner the biggest, littlest, or middle size one according to the particular test situation.

Results. The same factors were considered in the tabulation of the results of this series as were considered in Series X.

In table 4, the number of errors made in relation to the size requested is given. We see that although the number of children who were correct in their selection of the big forms was less than the number of those who were incorrect in their selection of the little forms, the total number of errors made to the request for the biggest was greater than for the little form. Ten children made 61 errors in the selection of the biggest and 12 children made 48 errors in the selection of the little card. This gives a percentage of correct choices of 88 for the biggest and 91 for the littlest form. The number of errors made in selecting the middle size was significantly larger. Only 6 out of 34 children were constantly correct in their selection of this size. There was a total number of errors for the group of 264, which gave a percentage of correct choices of only forty-eight. The six children who were correct in their selections of this size were correct also in all their selections of the big and little forms. The youngest child to choose all forms correctly was three years and three months; the others ranged from three years and seven months in age to four years and eight months. The percentage of errors in 45 choices ranged from zero to sixty-seven, with a mean of 22.

The various arrangements of the sizes used made it possible to have 6

TABLE 4

Series Y

Errors made in relation to size requested

REACTOR	AGE	NUMBER OF ERRORS				PER CENT ERRORS IN 45 CHOICES
		Size requested				
		Big	Little	Middle	Total	
1	2–4	6	2	15	23	51
2	2–3	0	0	14	14	31
3	3–4	0	0	2	2	04
4	3–6	0	0	0	0	00
5	3–4	0	0	1	1	02
6	3–9	0	2	2	4	09
7	3–1	0	0	11	11	24
8	3–5	1	0	15	16	35
9	4–2	4	0	2	6	13
10	4–1	0	0	14	14	31
11	3–1	0	0	12	12	24
12	2–8	0	0	12	12	24
13	3–5	0	1	10	11	24
14	2–4	13	0	9	22	49
15	3–9	0	0	0	0	00
16	4–8	0	0	0	0	00
17	4–2	0	0	0	0	00
18	4–8	0	2	5	7	15
19	3–7	0	1	15	16	35
20	2–11	4	2	7	13	29
21	2–7	6	3	14	23	51
22	3–10	0	0	8	8	18
23	4–10	0	0	0	0	00
24	4–8	0	0	0	0	00
25	4–10	0	0	1	1	02
26	4–11	0	1	6	7	15
27	3–7	6	0	15	21	47
28	3–8	0	0	8	8	18
29	2–3	7	10	11	28	62
30	3–6	0	0	1	1	02
31	2–3	3	15	12	30	67
32	2–5	11	3	12	26	58
33	3–9	0	0	15	15	33
34	3–0	0	6	15	21	47
Total errors		61	48	264	373	
Number of choices		510	510	510		
Per cent wrong		12	09	52		
Per cent correct		88	91	48		

TABLE 5

Series Y

Percentage of correct responses for varying differences between size of form requested and of form selected

REACTOR	DIFFERENCE IN INCHES BETWEEN DIAMETERS OR LENGTH OF SIDES						MEAN
	2	1½	1	¾	½	¼	
1	100	83	67	100	70	61	80
2	100	100	83	100	80	72	89
3	100	100	97	100	100	95	99
4	100	100	100	100	100	100	100
5	100	100	95	100	100	100	99
6	100	100	100	100	100	78	96
7	100	100	100	100	80	72	92
8	100	100	90	100	80	61	88
9	100	100	89	100	97	83	95
10	100	100	83	100	80	72	89
11	100	100	100	100	80	67	91
12	100	100	95	100	80	72	91
13	100	100	83	100	87	78	91
14	100	100	83	100	70	45	83
15	100	100	100	100	100	100	100
16	100	100	100	100	100	100	100
17	100	100	100	100	100	100	100
18	100	100	83	100	90	95	95
19	100	100	85	100	80	60	87
20	67	100	78	100	87	83	86
21	100	100	67	100	67	60	82
22	100	100	100	100	80	89	95
23	100	100	100	100	100	100	100
24	100	100	100	100	100	100	100
25	100	100	100	100	100	95	99
26	100	100	95	100	90	83	95
27	100	67	78	67	80	67	76
28	100	100	100	100	87	78	94
29	83	83	56	83	63	67	72
30	100	100	100	100	100	95	99
31	33	50	45	50	61	83	54
32	67	67	72	67	70	67	68
33	100	100	83	100	80	67	88
34	100	100	78	100	73	56	84
Mean	95	95	87	96	86	79	

size differences in the 6 steps of this phase of the experiment. Table 5 shows us the percentage of correct responses for varying differences be-

tween the size of the form requested and the form selected. The actual measurements of these differences in inches were 2; 1.5; 1; 0.75; 0.50; and 0.25. The mean per cents of correct choices for the group of 34 children for these differences between the size of the form requested and the form selected were 95, 95, 87, 96, 86, and 79, respectively. These percentages indicate greater difficulty for the smallest differences in size of forms, with the exception of the one inch difference. This variation in trend appears to be due to a few low scores for that size difference that were highly influential upon the mean for so small a group. The trend toward greater difficulty with smaller size differences is indicated by the decrease in percentage correct for the majority of the group. In this table will be found also the mean of the percentages of correct choices for each child for all these size differences. The range was from fifty-four to one hundred per cent correct.

The results were analyzed with regard to the possible effect of the order of presentation of the three sizes upon the accuracy of selections. Table 6 shows that the mean percentage of correct selections for the three orders BLM, MBL, and LMB was 76, 75, and 76, respectively. This would indicate that the order of presentation did not influence the selections.

The number of errors made by each child for each of the three forms used was approximately the same. Nine children made all their selections of may be seen in table 7. The total number of errors made for each form circles and squares correctly, and 10 children made their selections of triangles correctly.

TABLE 6

Series Y

Percentage correct for order of presentation

REACTOR	PERCENTAGE CORRECT		
	Order presented		
	BLM	MBL	LMB
1	47	47	53
2	67	67	73
3	87	100	100
4	100	100	100
5	93	100	100
6	93	80	100
7	73	73	80
8	60	67	67
9	67	73	67
10	93	93	73
11	73	73	73
12	80	73	67
13	67	67	93
14	47	47	60
15	100	100	100
16	100	100	100
17	100	100	100
18	87	73	93
19	60	67	67
20	73	80	60
21	67	33	47
22	80	87	80
23	100	100	100
24	100	100	100
25	100	93	100
26	87	80	87
27	53	53	53
28	100	73	73
29	27	53	33
30	100	100	93
31	40	33	27
32	47	40	40
33	67	67	67
34	40	60	60
Mean...	76	75	76

Only 15 children commented on the sixth step of this series in which all three sizes of the 3 forms presented

TABLE 7

Series Y

Errors made in relation to form presented without reference to size requested

REACTOR	NUMBER OF ERRORS			
	Position and form presented			Total
	BLM Circles	MBL Squares	LMB Triangles	
1	8	8	7	23
2	5	5	4	14
3	2	0	0	2
4	0	0	0	00
5	1	0	0	1
6	1	3	0	4
7	4	4	3	11
8	6	5	5	16
9	1	1	4	6
10	5	4	5	14
11	4	4	4	12
12	3	4	5	12
13	5	5	1	11
14	8	8	6	22
15	0	0	0	00
16	0	0	0	00
17	0	0	0	00
18	2	4	1	7
19	6	5	5	16
20	4	3	6	13
21	5	10	8	23
22	3	2	3	8
23	0	0	0	00
24	0	0	0	00
25	0	1	0	1
26	2	3	2	7
27	7	7	7	21
28	0	4	4	8
29	11	7	10	28
30	0	0	1	1
31	9	10	11	30
32	8	9	9	26
33	5	5	5	15
34	9	6	6	21
Total errors..	124	127	122	373
Number of choices.....	510	510	510	
Per cent wrong.....	24	25	24	
Per cent correct.....	76	75	76	

were alike. All the other children selected a form without saying anything. The remarks are recorded below. The numbers representing particular children correspond to those used in the tables.

These comments give emphasis to the results from the other forms in showing that some children have a clear perception of relative differences. Some children show stability in judgments of size relations and others appear less secure, indicating that the ages studied form a period of rapid development of concepts of magnitude.

Summary. The results of Series Y are in agreement with those found in the preliminary series. The majority of the children had little trouble in making their selections when the biggest and the littlest forms were requested, but most of them seemed unable to select the middle size of the three forms, regardless of the actual differences in size between the forms. Although the largest differences were between the two extremes of the three presented, the differences between the middle-size in relation to the other two were large and the children had no difficulty in reacting to those differences when they involved selections of the big or little.

The concept of middle-sizedness proved to be much more difficult than that of big or little size. As has been pointed out, the factors of age, order of presentation, and forms used seemed to have been insignificant in their influence upon the accuracy of selections.

Retest, Series Y. A retest in Series Y was given to a group of fifteen children after a summer vacation. This

REACTOR	AGE	SIZE REQUESTED	REMARKS
2	2–3	Little	"Well, they're all little."
5	3–4	Big	"I can't find the biggest one."
		Middle	"They're so little I don't know which is the middle-size one."
7	3–1	Middle	"You mean that big one?" (The forms in the other five steps had been placed in the order MBL.)
9	4–2	Big	"Didn't look like the biggest one."
			"Had to look carefully 'cause I had to see which was the biggest one."
		Little	"I can't tell which is the littlest one. They seem all big, don't they?"
		Middle	"I don't see any to give you. I'll give you this one." (Chose one on his right.)
10	4–1	Big	"It hasn't any biggest one."
			"There isn't any biggest one on this one."
		Little	"They're all little."
		Middle	"Those are little."
11	3–1	Big	"Where is it?"
12	2–8	Big	"It's no big one. This one must be it." (Handed me one on her left, where the big one had been in the previous five steps where the position had been BLM.)
13	3–5	Middle	"These were the same size, weren't they?"
14	2–4	Big	"These littlest ones. Those are little ones. Those are little ones."
		Middle	"All these middle-size ones."
26	4–11	Big	"Where's the biggest one?"
27	3–7	Big	"Was that the biggest one?" (Chose one in middle. Order was LMB.)
16	4–8	Middle	"They're so small, aren't they? I don't know what's the matter with them."
19	3–7	Middle	"They're all middle size."
23	4–10	Little	"I can hardly tell which is the little one of these." (On the following day when the various sizes in the first step were presented she said: "I know which is the middle size of these because the middle-size one is more middle-size."
		Middle	"I can hardly tell. Could'nt tell with those because they're all the same size."
25	4–10	Little	"They're all little ones, aren't they? Oh, is this the one? It looks like it." (Chose the one on his right.)

was done in order to find out what effect their experiences during those four months would have upon the

accuracy of their selections, and to refamiliarize the children with the test situation before introducing the next phase of the experiment. The method of procedure was the same as that used in the original test.

Results. The children made no errors in their choices of the big forms, as is shown in table 8, only 2 errors when making a selection of the little forms, and 75 errors when selecting the middle-size forms. Three children made all their selections of the 3 sizes correctly. The percentage of errors in 45 choices ranged from zero to thirty-three, with a mean of 11.

TABLE 8

Series Y, Retest

Errors made in relation to size requested

REACTOR	AGE	NUMBER OF ERRORS				PER CENT ERRORS IN 45 CHOICES
		Size requested				
		Big	Little	Middle	Total	
1	3–1	0	0	11	11	24
2	3–0	0	0	3	3	07
3	4–0	0	0	6	6	13
4	4–3	0	0	1	1	02
5	4–0	0	1	3	4	09
6	4–6	0	0	0	0	00
7	3–10	0	0	4	4	09
8	4–1	0	1	14	15	33
9	4–10	0	0	6	6	13
10	4–9	0	0	0	0	00
11	3–9	0	0	1	1	02
12	3–5	0	0	1	1	02
13	4–4	0	0	10	10	22
14	3–0	0	0	15	15	33
15	4–6	0	0	0	0	00
Total errors		0	2	75	77	169
Number of choices		225	225	225		
Per cent wrong		00	00.8	33		
Per cent correct		100	99.2	67		

The mean percentages of correct choices for the six differences in size between the forms requested and those selected are tabulated in table 9. For the size differences of 2, $1\frac{1}{2}$, 1, $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{1}{4}$ inches we find mean percentages of 100, 100, 96, 100, 94, and 87 respectively. In other words, the difference of 2 inches, $1\frac{1}{2}$ inches, and $\frac{3}{4}$ inch were chosen correctly 100 per cent of the time; the difference of 1 inch was chosen correctly 73 per cent of the time; that of $\frac{1}{2}$ inch was chosen correctly 40 per cent of the time; and the difference of $\frac{1}{4}$ inch 20 per cent of the time.

TABLE 9

Series Y, Retest

Percentage of correct responses for varying differences between size of form requested and form selected

REACTOR	DIFFERENCE IN DIAMETER OR SIDE, IN INCHES						MEAN
	2	$1\frac{1}{2}$	1	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	
1	100	100	83	100	83	83	91
2	100	100	100	100	97	89	98
3	100	100	100	100	90	83	95
4	100	100	100	100	100	95	99
5	100	100	100	100	97	83	97
6	100	100	100	100	100	100	100
7	100	100	100	100	97	83	97
8	100	100	83	100	83	61	88
9	100	100	100	100	90	89	96
10	100	100	100	100	100	100	100
11	100	100	100	100	100	95	99
12	100	100	100	100	100	95	99
13	100	100	89	100	87	78	92
14	100	100	83	100	80	67	88
15	100	100	100	100	100	100	100
Mean	100	100	96	100	94	87	96

Table 10 shows us the mean percentage of correct choices for the order of presentation. We see that for the

order BLM the group made a mean percentage of correct selections of 87, for the order MBL a mean percentage of 87, and for the order LMB a mean percentage of 92.

An analysis of the number of errors made for the three forms used is shown in table 11. We find that 18, or the fewest errors, were made for the tri-

TABLE 10

Series Y, Retest

Percentage correct for order of presentation

REACTOR	PERCENTAGE CORRECT			
	Order presented			Total
	BLM	MBL	LMB	
1	80	67	80	227
2	93	93	93	279
3	80	87	93	260
4	100	93	100	293
5	80	93	100	273
6	100	100	100	300
7	87	100	87	274
8	67	60	73	200
9	100	100	100	300
10	93	80	87	260
11	93	100	100	293
12	100	93	100	293
13	67	67	100	234
14	67	67	67	191
15	100	100	100	300
Mean.	87	87	92	

angles, 30 for the squares, and 29 for the circles.

A comparison of the first and second tests in Series Y shows us a decided improvement in the retest. There were 24 errors in the selections of the big forms in the first test and none in the retest. In the selections for the little forms in the first test there were 5 errors and in the retest only 2. In the selections of the middle-size forms there were 119 errors in the first test and 75 in the retest. One child who had made 14 errors out of 15 selections for the middle-size form in the first test made no errors for this size in the retest.

TABLE 11

Series Y, Retest

Errors made in relation to form presented without reference to size requested

REACTOR	NUMBER OF ERRORS			
	Form presented			Total
	BLM Circles	MBL Squares	LMB Triangles	
1	3	5	3	11
2	1	1	1	3
3	3	2	1	6
4	0	1	0	1
5	3	1	0	4
6	0	0	0	0
7	2	0	2	4
8	5	6	4	15
9	1	3	2	6
10	0	0	0	0
11	1	0	0	1
12	0	1	0	1
13	5	5	0	10
14	5	5	5	15
15	0	0	0	0
Total errors.	29	30	18	77
Number of choices.....	225	225	225	
Per cent wrong.....	13	13	08	
Per cent correct.....	87	87	92	

The trend for the mean percentages of correct choices for the varying differences between the size of the forms requested and those selected is the same for the retest as we found in the first test. All the children improved in their individual selections for the six differences except three.

The mean percentages of correct choices for these three children showed the largest decrease to be four points.

The mean percentages of correct selection for the order of presentation for the retest showed a considerable improvement, with a similar trend toward greater accuracy in selection of the middle-size form when it was presented in the middle position. Similar results were found in the analysis of the number of errors for the forms presented.

Method and Results

Series Z, Colored Forms. Colored forms were introduced in an attempt to find out whether the children would be influenced by color when the choice was to be made for size. It was assumed that the introduction of color might have an index of reliability of previous selections. The material for this series consisted of a set of colored geometric forms, circles, squares, and triangles of the same dimensions as those used in Series Y. They were presented in similar manner with the same size relationships maintained step by step as had been used in Series Y. In this series the sixth step in which all three forms were the same size was omitted. In the order of presentation of the colors, care was taken not to have any color occur more often than another, or in any position more often than another. The colors used were red, blue, yellow, and green. Black forms were mixed with the colored ones.

Instead of requiring the children to complete only one step of the experiment a day, as had been done in Series X and Series Y, they were requested to complete 3 steps 1 day and 2 the next. The 3 steps required nine choices a day, which took, at most, ten minutes. If, for any reason, the experimenter decided that a child was not concentrating on the task, the test period was shortened and he was requested to make only three choices. This series was presented to 24 children.

Results. Table 12 is a tabulation of the number of errors made in relation to the size of the form requested. We find that all the children except three were able to make correct selections when the biggest forms were requested. Those 3 children made 16 errors. Six children were incorrect in their selections of the littlest forms, and they made 20 errors altogether. These low percentages of errors, 4 per cent for the big form and 5 per cent for the little form, were not found for the middle size. When this size was requested 18 children made 140 errors, giving us a percentage of errors of 38, which is a considerable decrease in accuracy. Only 6 children were 100 per cent correct in all their selections of the 3 sizes.

Data for an analysis of the results with respect to the percentage of correct responses for the varying differences between the size of the form requested and the form selected are given in table 13. There were 6 possible differences, measured in inches, between the diameters or length of sides of the forms used. We find a mean per cent correct for the group of 98, 98, 91, 98, 90, and 84, for the differences of 2, $1\frac{1}{2}$, 1, $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{1}{4}$ inches respectively. The 2 children who chose incorrectly when there were

differences of 2 inches, $1\frac{1}{2}$ inches, and $\frac{3}{4}$ inch between the size of the form requested and that selected were the youngest in the group.

TABLE 12

Series Z

Errors made in relation to size requested

REACTOR	AGE	NUMBER OF ERRORS				PER CENT ERRORS IN 45 CHOICES
		Size requested				
		Big	Little	Middle	Total	
1	3–4	0	0	11	11	24
2	3–3	0	0	0	0	00
3	4–3	0	0	2	2	04
4	4–6	0	0	0	0	00
5	4–4	0	0	5	5	11
6	4–9	0	0	0	0	00
7	4–2	0	0	7	7	15
8	4–4	0	0	7	7	15
9	5–1	0	0	4	4	09
10	5–2	0	0	0	0	00
11	4–1	0	0	0	0	00
12	3–10	0	0	0	0	00
13	4–8	0	1	2	3	07
14	3–4	0	0	15	15	33
15	4–9	0	0	1	1	02
26*	4–11	0	1	15	16	35
27	3–9	3	2	9	14	31
28	3–10	0	0	10	10	22
29	2–5	4	6	12	22	49
30	3–8	0	0	3	3	07
31	2–5	9	7	10	26	58
32	2–7	0	3	10	13	29
33	3–11	0	0	9	9	20
34	3–1	0	0	8	8	18
Total errors.....		16	20	140	176	
Number of choices...		360	360	360		
Per cent wrong.....		04	05	38		
Per cent correct.....		96	95	62		

* The reactors designated in previous series by the numbers 16–25 were not tested in Series Z.

In table 14, we found that the mean percentage of correct choices was greatest for the triangles, the 3 sizes of which were always placed in the order LMB. If the differences between the triangles and the squares and circles had been greater, we may have explained it by the fact that the triangles were presented last, but the difference is so slight that this factor may be considered negligible.

TABLE 13

Series Z

Percentages of correct responses for varying differences between size of form requested and form selected

REACTOR	DIFFERENCE IN INCHES BETWEEN DIAMETERS OR LENGTH OF SIDE						MEAN
	2	$1\frac{1}{2}$	1	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	
1	100	100	83	100	87	78	91
2	100	100	100	100	100	100	100
3	100	100	100	100	100	89	98
4	100	100	100	100	100	100	100
5	100	100	100	100	90	89	96
6	100	100	100	100	100	100	100
7	100	100	100	100	90	78	95
8	100	100	89	100	90	89	95
9	100	100	100	100	93	89	97
10	100	100	100	100	100	100	100
11	100	100	100	100	100	100	100
12	100	100	100	100	100	100	100
13	100	100	95	100	100	89	97
14	100	100	83	100	80	67	88
15	100	100	100	100	90	100	98
26	100	100	83	100	80	61	87
27	100	100	78	100	80	45	84
28	100	100	89	100	87	78	92
29	83	83	72	83	70	72	77
30	100	100	100	100	97	89	97
31	83	67	61	67	73	67	69
32	100	100	83	100	80	72	89
33	100	100	83	100	90	83	93
34	100	100	83	100	97	95	96
Mean.	98	98	91	98	90	84	85

The order of presentation of the 3 sizes had as little influence upon the

accuracy of selections in this series as in the two previous series. The mean per cent of correct choices for the orders BLM, MBL, and LMB were 82, 84, and 85, respectively. The

TABLE 14

Series Z

Percentage correct for order of presentation

REACTOR	PERCENTAGE CORRECT		
	Form and Order presented		
	Circles BLM	Squares MBL	Triangles LMB
1	67	80	80
2	100	100	100
3	87	100	100
4	100	100	100
5	87	87	93
6	100	100	100
7	80	87	87
8	87	87	80
9	100	100	100
10	87	100	87
11	100	100	100
12	100	100	100
13	93	93	93
14	67	67	67
15	100	100	93
26	67	67	60
27	53	60	93
28	100	67	67
29	33	60	60
30	93	100	87
31	20	47	60
32	73	67	73
33	80	80	80
34	93	67	87
Mean...	82	84	85

individual scores can be found in table 14.

The number of errors made in relation to the form presented without reference to size requested is analyzed in table 15. We find that the total number for the circles, squares, and triangles was 65, 59, or 52 errors respectively. The greatest number of errors made by a child was 26 out of a possible 45 choices, made by a girl two years and five months old. These errors were for the three forms: 12

TABLE 15

Series Z

Errors made in relation to form presented without reference to size requested

REACTOR	ERRORS MADE			
	Position and Form presented			Total
	BLM Circles	MBL Squares	LMB Triangles	
1	5	3	3	11
2	0	0	0	00
3	2	0	0	2
4	0	0	0	0
5	2	2	1	5
6	0	0	0	0
7	3	2	2	7
8	2	2	3	7
9	2	0	2	4
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	1	1	1	3
14	5	5	5	15
15	0	1	0	1
26	5	5	6	16
27	7	6	1	14
28	0	5	5	10
29	10	6	6	22
30	1	0	2	3
31	12	8	6	26
32	4	5	4	13
33	3	3	3	9
34	1	5	2	8
Total errors..	65	59	52	176
Number of choices.....	360	360	360	
Per cent wrong.....	18	16	15	
Per cent correct.....	82	84	85	

for the circles, 8 for the squares, and 6 for the triangles.

An analysis of the relative accuracy of choices involving five colors, including black, is based upon data given in table 16. We see that the mean per-

TABLE 16

Series Z

Percentage correct for all sizes and forms

REACTOR	BLUE	GREEN	RED	YELLOW	BLACK	MEAN
1	70	86	71	75	78	76
2	100	100	100	100	100	100
3	100	100	85	100	90	95
4	100	100	100	100	100	100
5	89	85	100	91	82	89
6	100	100	100	100	100	100
7	89	87	100	90	69	87
8	90	75	87	89	80	84
9	100	100	87	82	90	92
10	100	100	100	100	100	100
11	100	100	100	100	100	100
12	100	100	100	100	100	100
13	90	100	78	100	100	94
14	67	67	83	64	60	68
15	100	100	100	100	90	98
26	75	67	83	54	55	65
27	87	67	62	64	50	66
28	78	78	85	73	87	80
29	57	60	72	44	83	63
30	90	100	85	100	90	93
31	28	50	55	46	37	43
32	100	55	75	67	50	69
33	78	80	85	75	85	81
34	80	78	85	83	85	82
Mean..	86	85	86	83	82	84

centages of correct selections for blue, green, red, yellow, and black were 86, 85, 86, 83, and 82, respectively. The small differences in errors for the varying colors indicate that the color of the form had little influence upon the selections made for relative size.

Although there were 16 errors made in the selection of the big form, all of them were made by the group of children numbered in table 12 from twenty-six to thirty-four. The entire series of tests from X to Z had been presented to these children within a period of six months. The first group of 15 children received the tests over a period of a year and three months. They received also a retest in Series Y which gave them greater familiarity with the test, and a period during which added experiences doubtless increased their ability to see abstract relationships. None of the 15 children made an error when selecting the big form in this series. Since we find the same trend in the selections of both the little and middle-size forms, the lengthened period and additional testing were doubtless influential factors in the selection of all three sizes. Six children out of nine who were given all 3 series during six months chose the big form correctly. They included a child of four years and eleven months, and one two years and seven months. Age does not seem to have been any more influential in this series than in the two previous series, except that the two children who made the greatest number of errors in all their selections were the youngest in the group. However, the child who came third in the total number of errors was the oldest in the group. Two children made all their selections for the middle size forms incorrectly. They both chose the smallest forms which were in the intermediate position when the middle size was first requested. These children were three years and four months, and four years and eleven months of age.

Summary. In Series Z, we have considered the factor of color as an influential factor in selection for relative size. We find that the results resemble closely those found in Series Y. The results from the color series give additional evidence of the greater difficulty in perception of the relation of middle size than for that of little or big. It is also shown that, in general, the greater the difference between forms, the more accurate is the choice. This is in agreement with the results of Series Y. We have also found that age, form, and the order in which the sizes were presented have probably not been determining factors in the choices.

The introduction of colored forms which might be assumed to introduce an interfering factor gives results that emphasize the early development of the concept of magnitude, though particular relations between sizes of objects, as middle size, are not equally developed at a given age.

CONCLUSION

The results from this study show that at the age of 3 years some children have developed concepts of magnitude though instability in perceptual reactions to varying relations between the sizes of objects is manifested. Inaccuracy in response to some situations does not indicate absence of a concept of size. This is indicated by the large percentage of children who make correct responses in selection of the largest object, though in another series that same object may have been the smallest. There is a perception of the relative difference in size. Correct choices of the smallest object were not so frequent as for the biggest though many children of the group were consistently correct.

The perception of the middle-size relation, in which the child must perceive that one object is smaller in relation to another object though it is correspondingly larger than the third object, is not a well developed concept at the ages studied. However, some children under five are capable of making correct responses in situations demanding the perception of intermediacy.

The extent of the differences in size influences slightly the response made. If the differences in size between objects are very small, the discrimination of the differences becomes difficult, and the perception of relative differences becomes increasingly inaccurate. With the size differences presented in this study, the three relations were perceived for all sizes though the middle-size relation was more difficult to perceive. Responses to the smaller size differences show slight increase in inaccuracy.

The tests for stability of the concept of magnitude—the color series and the presentation of a series with no difference in size of objects—substantiate the conclusion that some children develop a concept of magnitude earlier than others. Other children perceive differences in size but are not stable in perception of relative differences, under the varying conditions of presentation.

Individual differences in response do not clearly indicate definite age differences in the ability to select objects with reference to relative size. There is a trend toward less accuracy

in the younger children but some of this group excel some in the older group. Below 3 years of age there was a tendency toward making the same selection throughout the series. This would seem a failure to interpret the instructions. Preference for certain sizes or certain positions may have been influential. Control in the test procedure was not sufficient to state from the results whether the children perceived the relations. It is evident that some children 3 years of age have formed a concept of magnitude. The results point to the conclusion that the children were not influenced in their selections by the forms of the objects presented; that the sizes requested were presented in different orders did not seem to affect their choices; and also that the introduction of color in the last series did not affect the accuracy of their choice. The children's selections, then, must have been made after consideration of the sizes themselves. The conclusion that the child's ability to make perceptual judgments was a basis of his choice, seems justified from the data presented.

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Vita

Martha Elizabeth Thrum was born February 5th, 1901, in Honolulu, Hawaii. She attended Mills College, California from 1921 to 1925 and received her A.B. degree in 1925. The following year she went to the Merrill-Palmer School in Detroit for a year's training in nursery school work. In 1926 to 1928 she was director of the nursery school group at the Children's Community Center in New Haven, Connecticut. The years 1928 to 1931 were spent at Vassar as a teacher in the nursery school. She has been at the Johns Hopkins University since the fall of 1931, studying in the department of psychology.